Will an air purifier help?

Yes. The air in an infectious disease ward, ICU ward and operating theatre is cleaned by True HEPA filters. This is the highest industry standard for protection against airborne nosocomial infections etc. >>More on HEPA and SARS

Channel i News reports on the Honeywell air purifier and SARS.
>> view (broadband | 56K)

Well if the filters are that good, there won't be spread of infections within hospitals.

Like all medical efforts, including medication and surgeries, nothing is guaranteed. And infectious diseases are not just spread by going airborne - it is also spread by contact, which filters cannot help. It is all about *reducing* the chances of infection, and *increasing* the chances of recovery. Without the filters, the spread of the disease would have been far worse. This standard represents the best defence for both hospitals and home.

Will I get the same level of protection as the hospital?

Hospital systems are typically turnkey equipment involving not only the air handling units and ventilation systems, but also strict procedures for entry and exit to and from the ward. For example, masks may be required, and the relative air pressures between adjacent rooms are considered. So, the short answer is, no. But short of spending hundreds of thousands

to millions of dollars, using a medical-grade air purifier is still the best defence for the home.

Which air purifier should I get?

What do the doctors say? Honeywell Enviracaire is the Number One choice of US doctors. It is also recommended by brand by the American Lung Association. It is a US FDA Class II Medical Device. And it has been tested by PSB to remove >99% of germs, mould and yeast.

And unlike other technologies (see below for details), the Honeywell technology kills germs not by releasing harmful gases (like plasmacluster or ozone) that are also potentially harmful for the family. Thus the Honeywell technology is totally safe.

What should I look for in a medical-grade air purifier?

Choosing a good air cleaner is very different from choosing a plasma TV or a hi-fi set. You can see and hear the quality of a TV or hi-fi set. But very few people can tell whether an air cleaner really does its job, because air is invisible. Only those who are very sensitive (e.g. people with perennial rhinitis or asthma) can tell whether the air cleaner is working well or not. So it is very important to know how to choose a good medical-grade air cleaner.

There are four things to look out for in a medical-grade air cleaner.

- **True HEPA filtration**. It should use True HEPA filtration, because this is the standard used in any serious medical applications, including hospital operating theatres where germ and contaminant control is critical. True HEPA filters achieve a *minimum* of 99.97% efficiency using the cleanroom-standard D.O.P. or *Sodium Chloroide* (NaCl) test. Actual operating efficiencies are higher. They are effective for removing not only germs, but submicron dust particulates at near 100% efficiency. But be careful not to confuse True HEPA with HEPA (or HEPA-type) filters - there is a difference. Make sure the manufacturers' box states "True HEPA".

- **High airflow.** Even if an air purifier has the stated efficiency, it is important to have a high airflow in order to move the air in the room into the air purifier and through the filters, and send it back into the room again. Hence the more powerful air purifiers tend to be a little bulkier because they use bigger motors.

  To be effective, an air purifier needs to clean the volume of air in a room from four to eight times an hour. i.e. the same air in the room would have passed through the air purifier 4 to 8 times in an hour. This is called Air Change Per Hour (ACH). The required ACH depends on the patient's condition, and also on the level of contamination in the room.

- **Safe**. Because users of medical-grade air purifiers tend to be sensitive individuals, who may already have a condition, it is very important that the air purifier does not add any harmful additives into the air that kill germs but also cause harm to the family. Some technologies actually add ozone or plasmaclusters or hydroxyl radicals into the air. Even trace quantities may be risky for such individuals.

- **Medical credentials.** You have to ask whether this particular model has many independent third-party medical credentials. Ask for original copies of the medical endorsements, and verify that the endorsers are truly credible medical authorities and not some design or industrial awards.
- **Filter and motor size.** Ask to see the filter size and motor size. You will be surprised what you are buying. Often, sleek designs have a small motor and filter, with a lot of empty space inside. Industrial-looking machines are often the ones that offer value-for-money by giving professional-sized motors and filters. The latter will not beautify your room, but it *will* effectively clean your room of contaminants.

This last point about third party medical references is most critical because two air purifiers with the same paper specifications may achieve very different results in real life. A good air purifier would have a long track record, and would have built up a solid reputation among the medical experts. Do not be afraid to look for a long list of independent medical references.

Other things to look for include:

- **Airtight casing.** Even if the filter may pass the cleanroom-standard D.O.P. test, the air cleaner casing may not. Many brands of True HEPA and HEPA air cleaners have leaky casings. This defeats the purpose, as the dust will follow the path of least resistance and leak through the casing, since a HEPA filter presents high resistance

because of its density.

- **How thick is the filter?** You may be getting a True HEPA filter, but are you getting a very big piece, or a small piece? This will determine the lifespan of the filter.
- **How easy is to maintain the machine?** Do you have to turn the machine over, or unscrew several screws in order to change the filters?

It is not surprising that the one brand of air purifier that meets the above criteria is the Honeywell Enviracaire series, since the division has been specialising in air filters since the 1970s.

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Is there a *real* difference between the different air purifier technologies?

Yes there is. The difference can be very wide. There are many air purifier technologies, and choosing one that is not suitable can yield very different results from what one would expect, no matter how much one paid for it. Worse yet, many products have side-effects that customers only find out about after they have bought it. Hence it is important to learn about the technologies.

Almost all air purifiers use a motor to move air into the apparatus and through its filter element and move the clean air back out into the air again. But the major difference is the type of filtration technology used:

True HEPA filter. This is the highest-end technology available today. True HEPA filters are used as the main filters in hospital operating rooms and ICU wards. It is also standard in cleanrooms. This is because True HEPA filtration has the highest efficiency (i.e. the ability to capture even radioactive minute dust particles) among the different filter classes. Germs are also trapped within the filter, where they eventually die due to moisture deprivation. Their remnants stay within the filters.

HEPA or HEPA-Type filter. Not all HEPA filters are True HEPA. HEPA or HEPA-type filters are lower-grade than True HEPA filters, and their efficiency range from 25% to 95% of a True HEPA's efficiency. However, very often, customers are misled to believe that they are buying True HEPA filters when in fact they are getting HEPA-type filters. Packaging often just state that they are HEPA filters (which is not wrong - it's just not True HEPA filters). So, do look out for the words "True HEPA" on the manufacturer's packaging (and not just on locally-produced brochures).

Plasma Cluster generator. These machines generate hydroxyl (OH) radicals in the air,. Because OH radicals are very effective in killing cells, single-celled organisms like germs are quickly killed. However, OH radicals are linked to diseases like cancer in humans, since humans are also made up of cells (see below for more details).

Photocatalytic generator. These machines shine UV light onto Titanium Oxide (TiO^2) which produces OH radicals. OH radicals are linked to diseases including cancer. In general this class is weak in protection against particulate matter, which is the major contaminant in a haze situation.

Ozonizer. These generate ozone in order to kill germs and remove odour. They are usually quite successful in doing this. However, because ozone is itself a dangerous contaminant (as listed by the US EPA and Singapore's National Environmental Agency), this should only be used in low traffic areas (like rubbish dumps).

UV Light generator. These generate UV Light to kill germs and other living organisms, as UV light is harmful to all living things. They usually can achieve a very high kill-rate. However, they do little to remove dust particulates, gases (e.g. VOCs or volatile organic compounds). Also, the remnants of the dead germs, fungi or pollen that have been killed by UV radiation would be recirculated back into the air.

Electret or electrostatic filter. These filters are given a permanent electrostatic charge which traps dust particles. The most common filters of this type are 3M filters, and some filters made to be fitted into the air-con. Their maximum efficiency is normally only 60% of a True HEPA, with the actual operating efficiency is far lower, usually lower than that of a HEPA-type filter. But they are cheaper to maintain.

Electronic air cleaner. These work in a similar way with electret filters, but are made of aluminum, and use electricity to charge the plates. Like the electret, their maximum efficiency is normally only 60% of a True HEPA, with the actual operating efficiency being far lower. Their advantage is that they are washable, so there are some savings. Their disadvantage is that they produce ozone, which is a contaminant, and they produce sparks

and "pop" sounds during operation.

Activated carbon filter. This is usually used as a prefilter (i.e. the filter used to trap larger particles to extend the lifespan of main filters), because of its usually low filtration rate. It is strong in removing odour. However, do check how thick and big the filter is, as some versions of carbon filters are so "sparse" that their effectiveness is extremely low.

Ionizer (coulomb force generator). These machines usually have no motor. They charge the air around them with negative ions, and the negatively-charged dust will then stick to the surrounding walls and tables. Some models allow you to put in paper "filters" which will collect the charged dust. The efficiency of these machines is so low that there is no standard test for them. Their main usefulness is not in cleaning the air, but in releasing negative ions, which are beneficial to health. On the flip side, they produce ozone in various amounts, which is hazardous to health.

For some third party review of the different technologies, see Straits Times and Mothers of Asthmatics.

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What exactly is True HEPA technology?

True HEPA stands for High Efficiency Particulate Arrestance, or High Efficiency Particulate Air. A True HEPA filter is made of *borosilicate* material, which is densely-packed glass fibres. A True HEPA filter cannot be called True HEPA unless it achieves 99.97% efficiency on the cleanroom-grade *dioctylphthalate* (D.O.P.) or equivalent *Sodium Chloride* (NaCl) test. This is the definition of the filter.

In either test, neutrally-charged *dioctylphthalate* or *Sodium Chloride* particles with a constant mean diameter of 0.3 microns (i.e. 3/10,000th of 1 mm), are passed through the filter. The capturing efficiency is then calculated. The diameter of 0.3 microns is used because this is the particle size that is most difficult for *any* filter to capture. Technically, 0.3 microns is the most *penetrating* particulate size. So measuring at 0.3 microns would give the *minimum* efficiency of the filter, as measuring at all other sizes would give a higher efficiency. This is the *most conservative* and *stringent* test.

Measuring at other particle sizes (e.g. 0.1 micron) would always yield a higher efficiency, and does not give a true picture of the filter's performance. A True HEPA will always be nearly 100.00% efficient at particle size of 0.01 or 0.001 micron.

Why is 0.3 microns the most difficult size to capture and not something smaller? This is because there are two major forces operating in any HEPA air cleaner:

- **Inertial impaction and interception.** These forces are more efficient at capturing particles larger than 0.3 microns.
- **Brownian diffusion**. This effect is more efficient at capturing particles smaller than 0.3 microns. However, the diffusion effect *only* operates in True HEPA or HEPA-type filters, and does not apply to other technologies. That is why a True HEPA will have very high efficiency (nearly 100.00%) at very small particle sizes, e.g. 0.001 micron).

These two forces are complementary. The particle size of 0.3 microns is where both forces have least effect, and hence it is the particle size most difficult to filter out. This is also potentially the most dangerous particle size for the human respiratory system, as it is so difficult to capture.

True HEPA filters are usually pleated, like a paper fan. This is to allow a much larger surface area to be presented to incoming dust particles. So it is not uncommon to find a True HEPA filter's actual size to be more than 10 times the cross-sectional area of the air intake area. This greatly increases the dust holding capacity of the filter, i.e. the capacity of the filter in terms of amount of dust that can be kept within the filter. The dust-holding capacity of a True HEPA filter far exceeds that of other types of filter materials.

The above characteristics make True HEPA filters ideal for medical or cleanroom purposes, because by definition, it can remove practically anything with 99.97% efficiency. And unlike other types of technologies, this efficiency goes up with time, not down.

And this is why only True HEPA filters are used as the main filters in hospital operating rooms, ICU wards, and industrial cleanrooms. In a contagious disease ICU ward for example, the True HEPA filters are needed to contain contagious germs in the air - once the

germs enter, they are trapped, at a quantifiable rate of a minimum 99.97% effectiveness. In such situations, the True HEPA filters are disposed as a biohazard.

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Wasn't True HEPA technology created to contain radioactive particles?

Yes, True HEPA technology developed out of the 1940s' classified Manhatten Project Atomic programme by the US Government. In the process of harnessing nuclear power, scientists had to come up with an extremely high-grade filter that can contain very small and dangerous radioactive particles.

Scientists focused on a particulate filter that could retain particulates, even those associated with the condensation of gases and liquid aerosols. It was established that 0.3 microns was the most *penetrating* particle size, and efforts led to the development of the True HEPA filter. In those days, it was called an "absolute filter" due to its virtually impenetrable nature, and the its cost was understandably very high. The acronym "True HEPA" came into being in the 1950s when the technology became commercialized.

Over the next 50 years, True HEPA technology evolved and progressed in tandem with advances in high tech industries like aerospace, pharmaceutical micro-electronics. With advances in surgery, and the need for contagious disease control, medical applications were quickly found.

These industries demanded higher and higher air cleanliness approaching that required in a toxic radioactive environment. WIth the widespread deployment of True HEPA technology because of its unparalleled performance, reliability and safety, its cost has dropped dramatically.

This price decline had the positive effect of making this radioactive-grade filter available not only to exclusive high tech industries and medical facilities, but also to the office or family who wants their air to be clean. It must be noted however, that the office or home using a True HEPA air purifier will never approach cleanroom standard of cleanliness, because the controls required to operate such a cleanroom (e.g. use of overalls, gloves, masks and caps) are not practical or possible in an office or home environment.

But given the current technology of air filtration, portable or ceiling mounted air purifiers mounted with medical-grade True HEPA filters would give the environment the purest air possible under the circumstances.

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Are there different grades of HEPA?

Yes. a HEPA (or HEPA-type) filter is made of the same *borosilicate* material as a True HEPA filter. The only difference is that it does not pass the 99.97% D.O.P. test. Usually, the highest efficiency achieved is 95%, and it could be as low as 25%.

So the consumer has to be very careful when choosing an air purifier. It is important to check the manufacturer's box (and not just locally printed brochures), to verify the words "True HEPA". Even if they state "99.97% efficient at removing pollen, cat dander etc" it is not enough, because these contaminants are usually much larger than 0.3 microns. So any HEPA-type can be 99.97% at particles higher than 0.3 microns (remember that 0.3 microns is the particle size that is hardest to filter, not anything larger or smaller).

Even among True HEPA filters, there are different grades.

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What is Reactive Oxygen Species technology?

Reactive Oxygen Species (ROS) is a term used to denote oxygen radicals like superoxide anions (O_2^-), hydroxyl radicals (OH), and certain non-radicals that are either oxidizing agents or easily convert into radicals, like ozone (O_3) and hydrogen peroxide (H_20_2) . A free radical is any species that is capable of independent existance and which contains one or more paired electrons.

Because ROS are highly reactive, they are very effective in killing bacteria and de-activating odour. They do so primarily by extracting hydrogen from the cells or gas, or by oxidizing them.

There are three broad groups of ROS technologies:

- plasma cluster technology
- photocatalyctic technology
- ozonizer technology

ROS do exist in nature, and they play an important role in pollution control and UV filtration among other things. While they are very useful in the atmosphere, they can be hazardous when in contact with humans. Also, when OH radicals react with volatile organic compounds, gases and odour, it is not always that the gases and odours break down into non-odorous and non-toxic versions - sometimes more toxic gases are formed instead.

ROS like hydroxyl (OH) radicals have been linked to various diseases including cancer, and ozone has already been listed by the World Health Organization, Environmental Protection Agency and Singapore's National Environmental Agency as a harmful contaminant.

The mechanics and pros and cons of each technology are covered below.

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What exactly is plasma cluster technology?

Plasma cluster technology involves the generation of positive $H^+$and negative O_2^- ions (also called superoxides) alternatively. These ion clusters are blown into the air and they diffuse to various parts of the room.

These ion clusters are attracted to airborne particulates (actually any matter), and collide with the particulates and also to one another. The collision of $2H^+$ and O_2^- creates very reactive OH radicals, otherwise known as hydroxyl radicals. Hydrogen peroxide (H_20_2) may also be formed, but these will also finally turn into OH radicals.

These OH hydroxyl radicals are very unstable, and each OH group will extract one hydrogen (H) atom from anything it comes into contact with, forming water (H_20). Extracting one hydrogen atom from a single-celled organism like bacteria will kill it. That is what makes plasma cluster technology so effective at killing single-celled organisms.

Fortunately, humans are not single-celled organisms. Our lungs, though extremely sensitive, are not made of single cells, and we will not die when exposed to OH radicals. However, the unstable OH radicals have been linked to diseases in humans including cancer (see below).

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If OH radicals are carcinogenic, why is its use not banned?

Like ozone (which is another harmful ROS, that is already listed by National Environmental Agency and World Health Organization as a contaminant harmful to humans), OH radicals do exist naturally in the atmosphere. However, the atmospheric concentration of OH radicals are small.

As important oxidants, both ozone and OH radicals play an important part in killing germs and pollution control within the atmosphere. However, this does not change the fact that human exposure to them presents a health risk. Afterall, it is the same properties that are so effective at killing single-celled organisms that present a risk to humans.

First, let us review the links between hydroxyl radicals, which is part of the harmful free radical family, with cell mutations, DNA destruction, various diseases including allergies (asthma, rhinitis, dermatitis) and cancer:

- **Journal of Allergy and Clinical Immunology** (peer-reviewed medical journal). Concludes that *"there is ample evidence that allergic disorders, such as asthma, rhinitis, and atopic dermatitis, are mediated by oxidative stress*," which is caused by excessive exposure to reactive oxygen species (ROS - hydroxyl radicals are part of this family), which leads to "*a damage of proteins, lipids, and DNA."* Mentions "*environmental exposure to air pollution and cigarette smoke*" as a source of such oxidative stress, thus clearly linking airborne ROS like OH radicals as "air pollution", not something good for the family. ***>>more***
- **Columbia University** Health Sciences Division, in an EPA (Environmental Protection Agency) sponsored research, found that arsenic causes cancer by first spurring production of superoxide, very unstable free radical that is quickly turned into

hydrogen peroxide. This in turn breaks down to *"hydroxyl radicals, extremely reactive and damaging free radicals that attack cell membranes and DNA to create mutations."* ***>>more***

- **Life Extension Foundation** reports on the devastating effects of hydroxyl radicals on the human body: *"It reacts at diffusion rates with virtually any molecule found in its path including macromolecules such as DNA, membrane lipids, proteins, and carbohydrates. In terms of DNA, the hydroxyl radical can induce strand breaks as well as chemical changes in the deoxyribose and in the purine and pyrirnidine bases."* ***>>more***
- **University of Natal:** hydroxyl radicals are "*highly reactive, oxidising most organic compounds at almost diffusion controlled rates (K> 10 per molar per second, Dorfman and Adams 1973). Due to its high reactivity it is indiscriminate, reacting with the first substrate available. It therefore has a high destructive and mutanogenic potential.*" ***>>more***
- **University of Canterbury** research links free radicals, including hydroxyl radicals with coronary heart disease, stroke, cancer, arthritis, alzheimers and cataracts. Cancer genes may be switched on by hyrdoxyl radicals causing mutations in our DNA. ***>>more***
- **Biochemical Journal** research reports that ROS (including OH hydroxyl radicals and ozone) "posess many characteristics of carcinogens, and mutagenesis could contribute to the initiation of cancer. ***>>more***

Smoking is linked to lung cancer, but it took several decades before firm action was taken, and even today it is not banned - it is just mostly controlled to protect non-smokers from secondary smoke. Partly because smoking does not guarantee lung cancer.

Similarly, exposure to OH radicals does not necessarily guarantee cell mutation, cancer and other age-related diseases.*

* Notwithstanding, as there has yet been no study that demonstrate that the use of OH radicals in air cleaners causes cancer (as seen in the tobacco industry, such studies require deep commitment by way of time, budget and independence), no one should conclude *a priori* that the use of such an air cleaner will lead to cancer.

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What exactly is photocatalyctic technology?

Photocatalyctic technology uses the action of UV light on a semiconductor material like Titanium Dioxide (TiO_2) to produce hydroxyl radicals.

Unlike the plasma cluster ion technology, which sends bipolar ions into the air which then collide to form OH radicals in the air, in the photocatalyctic method has the advantage of producing the OH radicals within the air purifier. So most of the germs and gas-phase VOCs react with the OH radicals and thus remove the OH.

However, since the air purifier needs to move large quantities of air in and out, it cannot be guaranteed that there are absolutely no hydroxyl radicals or gas-phase hydrogen peroxide (which turn into hydroxyl radicals) released into the air. Also, no one can guarantee that there are enough germs and proteins in the air to "mop up" all the harmful hydroxyl radicals generated by the photocatalytic process.

Since an air purifier is for health purposes, there are alternative technologies that do not generate harmful by-products in order to kill germs.

Furthermore a setback of the photocatalytic system is that while it is effective against single-celled organisms and VOCs, its effectiveness against particulates is very poor compared to True HEPA technology.

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What about ozonizer technology?

Of all the ROS technology, this is the most straightforward. As the name suggests, this class of equipment generates ozone. Ozone kills germs and deactivates VOCs and odour.

In contrast with OH radicals, ozone is a more stable and less reactive oxidant. Nonetheless, it has been listed by various governmental authorities, including Singapore's National Environmental Agency, as a contaminant hazardous to humans.

Ozone in the stratosphere is a good thing, blocking out harmful solar radiation. But ozone at

ground level and in contact with humans *is* hazardous.

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What about UV light technology?

These use UV Light to kill germs and other bioaerosols (living organisms suspended in the air - e.g. pollen, mould, yeast, fungi). If the air velocity is slow enough, it can achieve high kill rates, even 99.9%. The effectiveness is inversely proportional to the air velocity. This usually translates to small volumes of air being cleaned compared to other technologies, so overall effectiveness is reduced.

Also, because they do not normally use high-grade filters, the dead germs and other bioaerosols will be recirculated back into the air. They also cannot capture haze or dust particles with any respectable efficiency, unless they employ True HEPA media.

The UV light tubes will be degraded after about two years of normal operation, but consumers have no way to tell as there is no visual indicator. Since UV Light generators have casings that are tamper-proof (a casing that leaks can be dangerous as UV Light is dangerous to humans), consumers have to return the units to factory to get the tubes replaced.

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Wouldn't the True HEPA filter clog up very fast due to its small pore size?

If the True HEPA filter acted like a sieve to trap particles in its holes, then it would indeed clog up very fast. However, the True HEPA *borosilicate* material is such that at the microscopic level, a dust particulate entering the filter would be crashing into a complex system of tunnels intertwined throughout the depth of the filter. And the particulates will impact the walls of these tunnels and be trapped due to the impaction, interception and Brownian forces mentioned earlier. The dust particulate does not actually clog up the tunnel systems of the True HEPA media. Under normal usage with proper prefilter maintenance, the tunnels of a top-end True HEPA filter will take 3 to 5 years to clog.

Another reason is that a top-end True HEPA filter has many pleats and is very deep, so that the actual surface area exposed to dust particles is very much larger compared to the cross-sectional surface area of the airflow. Also, it is necessary to maintain a good dense prefilter in front of the True HEPA in order to trap the larger particles. Otherwise, the HEPA will indeed clog up much faster than the stipulated lifespan.

So, not every manufacturer can claim 3 to 5 years of expected lifespan of the top-end True HEPA equipment. Do check the HEPA quality before buying. It does make a difference.

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Some say HEPA filters are a breeding ground for germs and dust mites. Is this true?

This is a common misconception. True HEPA filters trap germs and other contaminants with at least 99.97% efficiency. These bioaerosols eventually die because of lack of moisture that they require. This is why only True HEPA filters are used where health or cleanliness is critical – e.g. hospital operating rooms, hospital ICU wards, and cleanrooms. Doctors and cleanroom engineers continue to prefer True HEPA filters because they are extremely effective at removing germs and other submicron contaminants from the air. In such places, True HEPA filtration remains the industry *standard* - it has the proven track record for removing radioactive particles, and it can certainly remove germs.

Also, it is unlikely that air cleaners trap dust mites. This is because although dust mites are generally invisible to the naked eye, they are too large to go airborne easily. However, when dust is disturbed, dust mite dropping (which is the real allergen causing allergic responses) is small and light enough to go airborne. It is this allergen that is trapped by True HEPA filters. Since few dust mites are ever captured in the filters themselves, there is little chance of them breeding. If they were every captured, they would die from lack of moisture.

If it were true that HEPA filters were breeding grounds for dust mites and germs, then they would not be used in hospitals and cleanrooms, would they?

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